

REPORT DOCUMENTATION PAGE

AFRL-SR-BL-TR-01-

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the gathering and maintaining the data needed, and completing and reviewing the collection of information. Send collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork

0028

1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE		3. REPORT TYPE AND DATES COVERED 15 June 1997 to 20 September 2000	
4. TITLE AND SUBTITLE Illumination and Temperature Invariant Recognition in Multispectral Infrared Imagery				5. FUNDING NUMBERS F49620-97-1-0492	
6. AUTHOR(S) Glenn Healey					
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Electrical and Computer Engineering University of California Irvine, CA 92697				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) AFOSR 801 North Randolph Street, Room 732 Arlington, VA 22203-1977				10. SPONSORING/MONITORING AGENCY REPORT NUMBER F49620-97-1-0492	
11. SUPPLEMENTARY NOTES					
12a. DISTRIBUTION AVAILABILITY STATEMENT Approved for Public Release.					
DTIC QUALITY INSPECTED 4 20010129 003					
13. ABSTRACT (Maximum 200 words) Significant progress has been made towards achieving the research objectives in the areas of physical modeling, algorithm development, and experimental evaluation. We have carefully analyzed the physics underlying the information of airborne hyperspectral imagery over the 0.4/~m-2.5tm spectral range which corresponds to the HYDICE and AVIRIS sensors. The new spectral radiance model includes reflected solar and scattered radiation as well as the effects of atmospheric gases and aerosols. We have shown using a statistical analysis of the radiance model that the variation in an object's spectral signature lies in a low-dimensional space. This result is the basis of a new maximum likelihood ATR algorithm that is invariant to illumination and atmospheric conditions. We have demonstrated that the new recognition algorithm significantly outperforms existing algorithms over a range of HYDICE and AVIRIS imagery over a range of conditions. We have also evaluated the use of linear models for representing mid-wave and long-wave infrared spectral reflectance functions.					
14. SUBJECT TERMS				15. NUMBER OF PAGES 5	
				16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT		18. SECURITY CLASSIFICATION OF THIS PAGE		19. SECURITY CLASSIFICATION OF ABSTRACT	
				20. LIMITATION OF ABSTRACT	

Final Technical Report 2000

Project Title: Illumination and Temperature Invariant Recognition
in Multispectral Infrared Imagery

Agency: Air Force Office of Scientific Research

Grant Number: F49620-97-1-0492

Program Manager: Dr. Abraham Waksman

Principal Investigator: Glenn Healey

Address: Electrical and Computer Engineering
University of California
Irvine, CA 92697

Phone: (949) 824-7104

Fax: (949) 824-2321

Email: healey@ece.uci.edu

URL: <http://www.cvl.uci.edu>

1 Objectives

The primary objective of this project is to develop algorithms for the reliable recognition of targets in multispectral infrared images under arbitrary illumination, atmospheric, and thermal conditions. The algorithms will be derived from a detailed physical model for infrared image formation and combine spectral and spatial characteristics of targets and backgrounds. The use of these algorithms to process imagery from airborne platforms will significantly improve battlefield awareness in several areas. Since the new algorithms can exploit arbitrary combinations of spatial and spectral characteristics in unconstrained environments, they will be especially valuable for recognizing partially concealed targets and camouflaged targets as well as distinguishing targets from decoys. Techniques developed in this work can be used to classify and register image areas independent of illumination and atmospheric conditions. The algorithms can also be used for material identification for applications such as determining terrain trafficability.

2 Status of Effort

Significant progress has been made towards achieving the research objectives in the areas of physical modeling, algorithm development, and experimental evaluation. We have carefully analyzed the physics underlying the formation of airborne hyperspectral imagery over the $0.4\mu\text{m}$ - $2.5\mu\text{m}$ spectral range which corresponds to the HYDICE and AVIRIS sensors. The new spectral radiance model includes reflected solar and scattered radiation as well as the effects of atmospheric gases and aerosols. We have shown using a statistical analysis of the radiance model that the variation in an object's spectral signature lies in a low-dimensional space. This result is the basis of a new maximum likelihood ATR algorithm that is invariant to illumination and atmospheric conditions. We have demonstrated that the new recognition algorithm significantly outperforms existing algorithms over a range of HYDICE and AVIRIS imagery over a range of conditions. We have also evaluated the use of linear models for representing mid-wave and long-wave infrared spectral reflectance functions.

3 Publications

- [1] D. Slater and G. Healey, "ATR in Multispectral Imagery using Physics-based Invariant Representations," ATRWG System and Technology Symposium, Redstone Arsenal, AL, October, 1997.
- [2] D. Slater and G. Healey, "A Method for Material Classification in AVIRIS Data with Unknown Atmospheric and Geometric Parameters," JPL Airborne Earth Science Workshop, January 1998.
- [3] G. Healey and D. Slater, "Exploiting an Atmospheric Model for Automated Invariant Material Classification in Hyperspectral Imagery," SPIE Conference on Algorithms for Multispectral and Hyperspectral Imagery IV, Orlando, April 1998.
- [4] D. Slater and G. Healey, "What is the Spectral Dimensionality of Illumination Functions in Outdoor Scenes?" IEEE Conference on Computer Vision and Pattern Recognition, Santa Barbara, June 1998.
- [5] G. Healey and L. Benites, "Linear Models for Spectral Reflectance Functions over the Mid-Wave and Long-Wave Infrared," *Journal of the Optical Society of America A*, to appear.
- [6] D. Slater and G. Healey, "Analyzing the Spectral Dimensionality of Outdoor Visible and Near-infrared Illumination Functions," *Journal of the Optical Society of America A*, 15(11), 2913-2920, November 1998.
- [7] G. Healey and D. Slater, "Image Understanding Research at UC Irvine: Automated Invariant Recognition in Hyperspectral Imagery," Proceedings of the DARPA Image Understanding Workshop, 631-639, 1998.
- [8] B. Thai and G. Healey, "Invariant Subpixel Material Identification in Hyperspectral Imagery," Proceedings of the DARPA Image Understanding Workshop, 809-814, 1998.
- [9] D. Slater and G. Healey, "Reflectance Estimation and Material Identification for 3D Objects in Outdoor Hyperspectral Images," Proceedings of the DARPA Image Understanding Workshop, 815-820, 1998.

- [10] B. Thai, G. Healey, and D. Slater, "Invariant Subpixel Material Identification In AVIRIS Imagery," JPL AVIRIS Workshop, February 1999.
- [11] B. Thai and G. Healey, "Invariant ATR for Subpixel Targets in Hyperspectral Imagery," ATRWG System and Technology Symposium, Monterey, March, 1999.
- [12] D. Slater and G. Healey, "Material Mapping for 3D Objects in Hyperspectral Images," SPIE International Symposium on Aerospace/Defense Sensing Simulation and Controls, Orlando, April 1999.
- [13] B. Thai and G. Healey, "Invariant Subpixel Target Identification in Hyperspectral Imagery," SPIE International Symposium on Aerospace/Defense Sensing Simulation and Controls, Orlando, April 1999.
- [14] G. Healey and D. Slater, "Invariant Recognition in Hyperspectral Images," Proceedings of IEEE Conference on Computer Vision and Pattern Recognition, Vol. I, 438-443, June 1999.
- [15] D. Slater and G. Healey, "A Spectral Change Space Representation for Invariant Material Tracking in Hyperspectral Images," SPIE International Symposium on Optical Science, Engineering, and Instrumentation (SPIE Annual Meeting), Denver, 18-23 July 1999.
- [16] P. Suen and G. Healey, "Modeling and Recognizing Hyperspectral Textures Under Unknown Conditions," SPIE International Symposium on Optical Science, Engineering, and Instrumentation (SPIE Annual Meeting), Denver, 18-23 July 1999.
- [17] G. Healey and D. Slater, "Models and Methods for Automated Material Identification in Hyperspectral Imagery Acquired Under Unknown Illumination and Atmospheric Conditions," IEEE Transactions on Geoscience and Remote Sensing, 37(6) 2706-2717, November 1999.
- [18] P. Suen, G. Healey and D. Slater, "Material Identification over Variation of Scene Conditions and Viewing Geometry," SPIE Volume 4049, Algorithms for Multispectral, Hyperspectral, and Ultraspectral Imagery VI, Orlando, Florida, April 2000.
- [19] Z. Pan, G. Healey and D. Slater, "Modeling the Spectral Variability of Ground

Irradiance Functions," SPIE Volume 4049, Algorithms for Multispectral, Hyperspectral, and Ultraspectral Imagery VI, Orlando, Florida, April 2000.

[20] G. Healey and D. Slater, "Lessons Learned: Technology transfer from terrestrial spectroscopy to biomedicine," SPIE Volume 3920, Spectral Imaging: Instrumentation, Applications, and Analysis, San Jose, January, 2000.